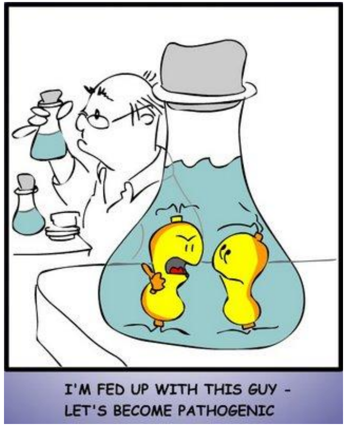
Evolution Simulations

Motivating Factors

- Understanding evolution of pathogen virulence
  - Ex: Different food sources elicit fast changes to bacterial virulence (Ketola, et al)
- Bioengineering of organisms
  - Ex: Programmed Evolution for Optimization of Orthogonal Metabolic Output in Bacteria (Eckdahl, et al)



"I find that they evolve better under pressure."

Outline of Simulations

- Population of organisms (**G**) in an Environment (**E(G,t)**) that potentially changes with time
- The Environment has finite resources that the organisms need

- Each organism has:
  - A genotype (**g**)
  - A birth rate **b**(**g, E(G,t)**)
  - A death rate **d(g, E(G,t)**)
  - A mutation rate **m(g**, **E(G,t)**)

Central Questions

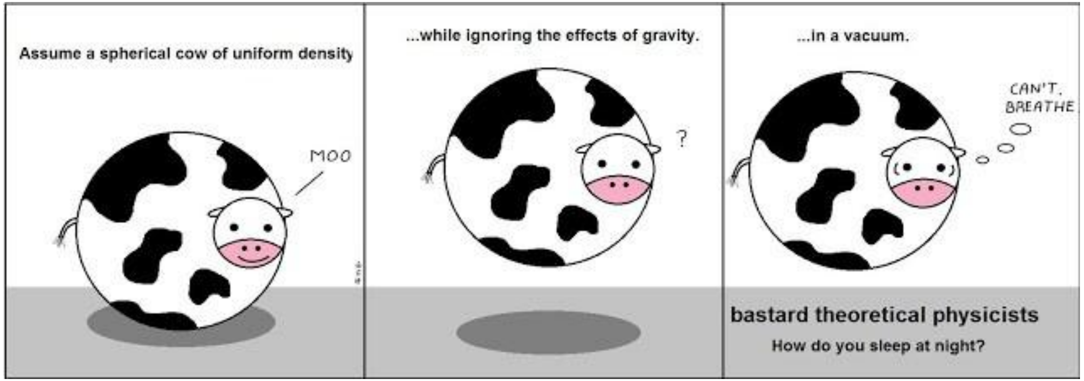
- What distribution of genotypes in the population are stable in stable environments?

- What happens to the genotype distribution as the resources in the environment change?

- What is the time frame in which the genotype distribution evolves?

Particular System

- Organism have **n** genes and **n + 1** possible genotypes
- Genes are binary: can be ‘A’ or ‘B’
- The Environment has 3 resources
  - ‘Water’ with capacity $\mathbf{C_W \gg 1}$ that is consumed by every organism
  - Food A with capacity $\mathbf{C_A \gg 1}$ is consumed by organisms with ‘A’ genes
  - Food B with capacity $\mathbf{C_B \gg 1}$ is consumed by organisms with ‘B’ genes

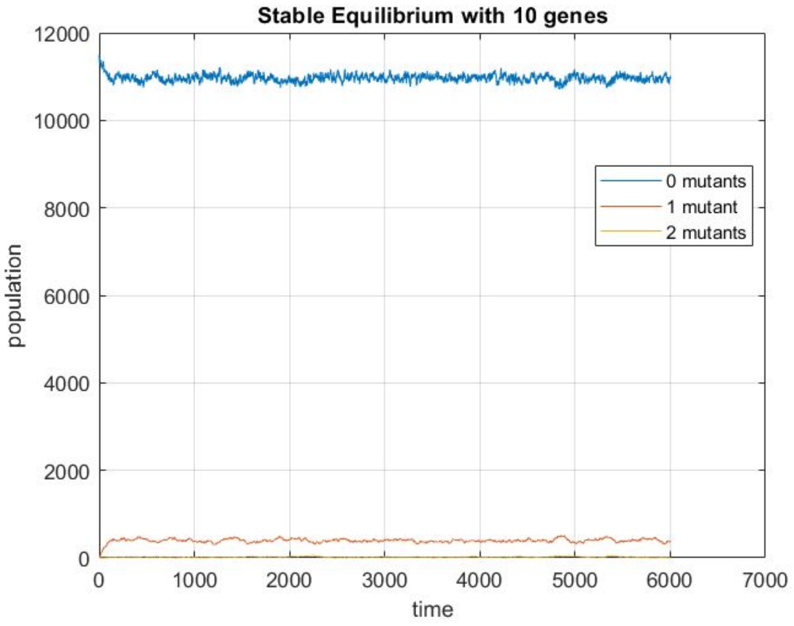


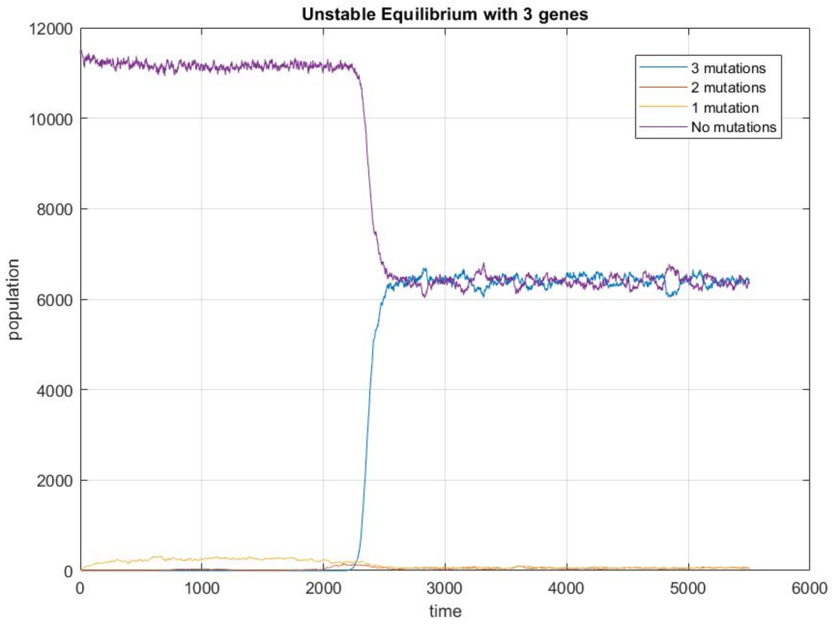
Key Functions

- death rate = constant
- mutation rate = constant
- birth rate =

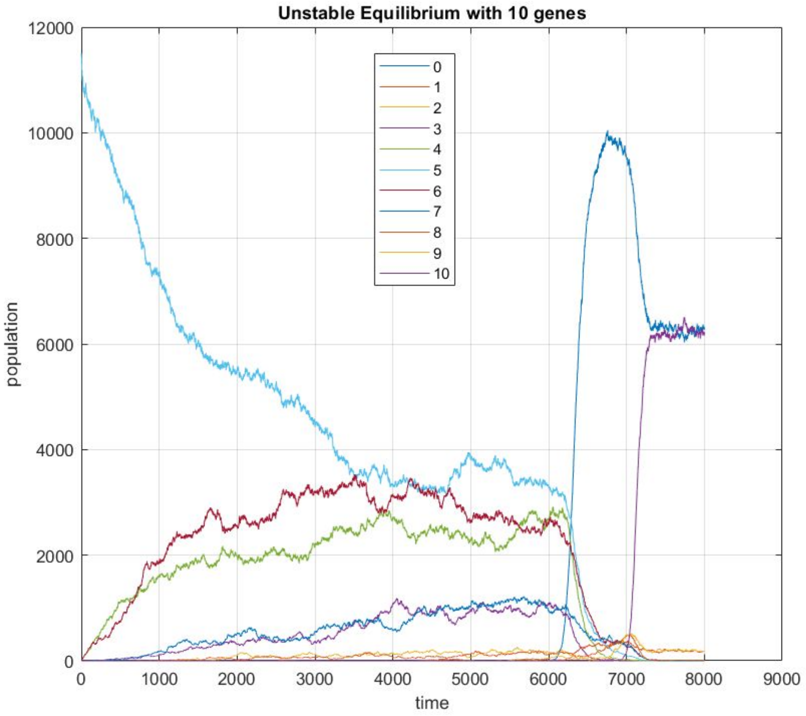
$$\left(\frac{m}{n}(b_A + r_A(m,n))e^{\frac{-1}{C_A}\sum\frac{m_i}{n}} + \frac{n-m}{n}(b_B + r_B(m,n))e^{\frac{-1}{C_B}\sum\frac{n-m_i}{n}}\right)e^{\frac{-N}{C_W}}$$

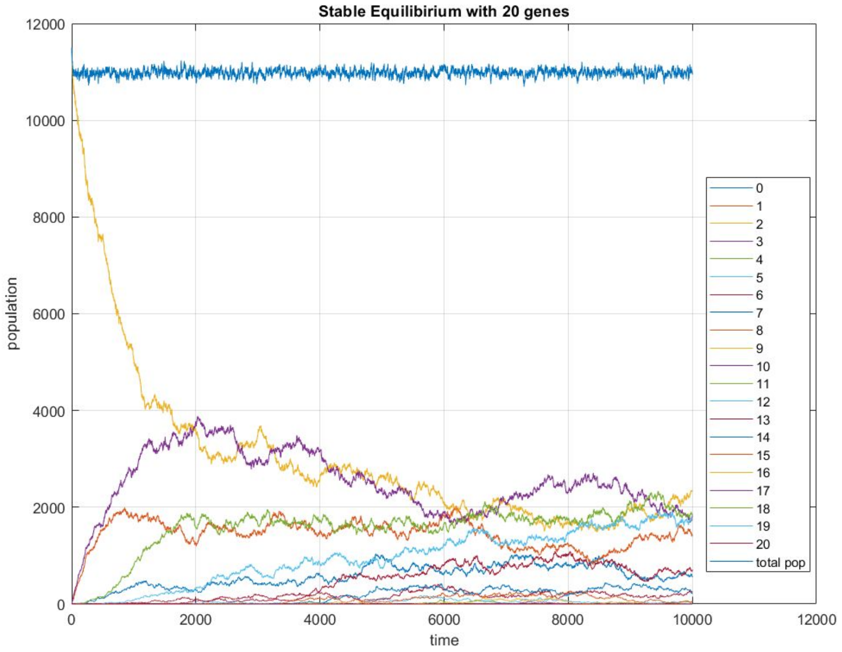
Experiment #1: Equilibria





Experiment #1: Equilibria





Evolution Forces

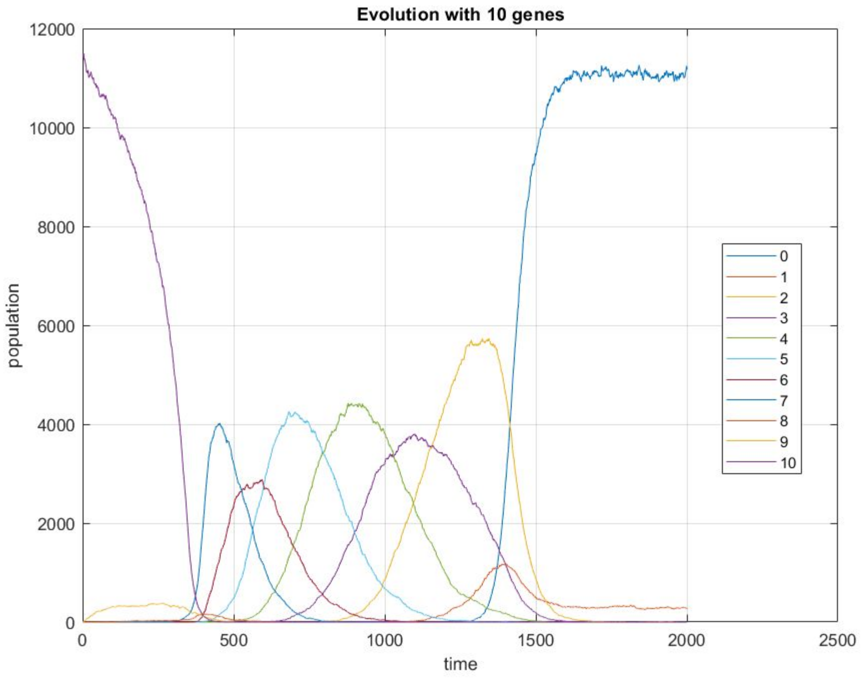
A population of a given genotype is favorable to grow when:

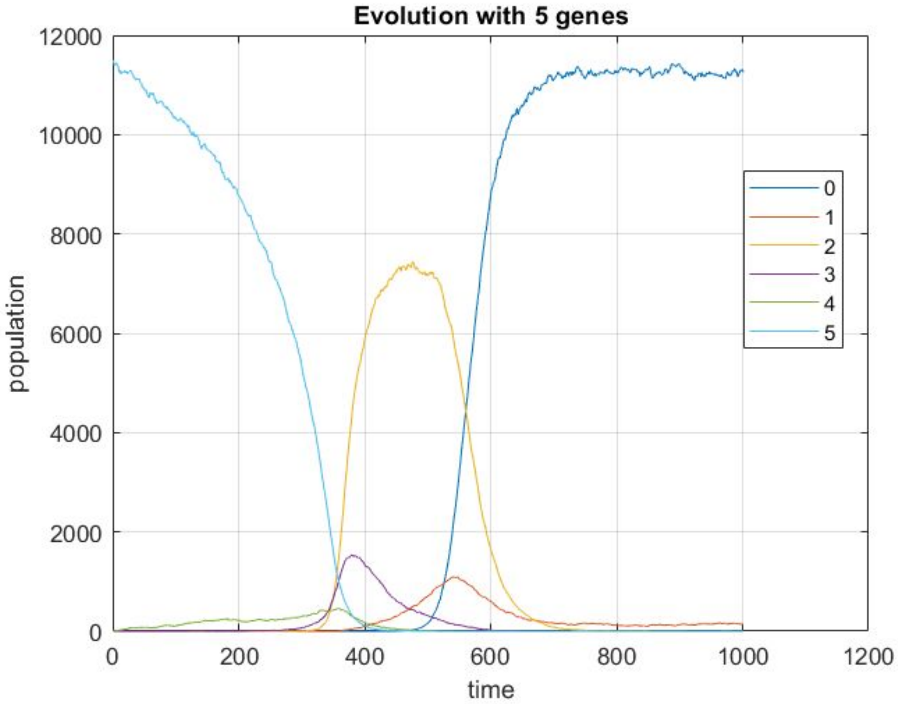
$$(\frac{m}{n}(b_A + r_A(m,n))e^{\frac{-1}{C_A}\sum\frac{m_i}{n}} + \frac{n-m}{n}(b_B + r_B(m,n))e^{\frac{-1}{C_B}\sum\frac{n-m_i}{n}})e^{\frac{-N}{C_W}} + M \cdot G > d$$

And the homogeneous genomes will always be favorable when:

$$r_i e^{\frac{-N}{C_i}} > \frac{1}{n}(1 - e^{\frac{-N}{C_i}})$$

Experiment #2: Evolution





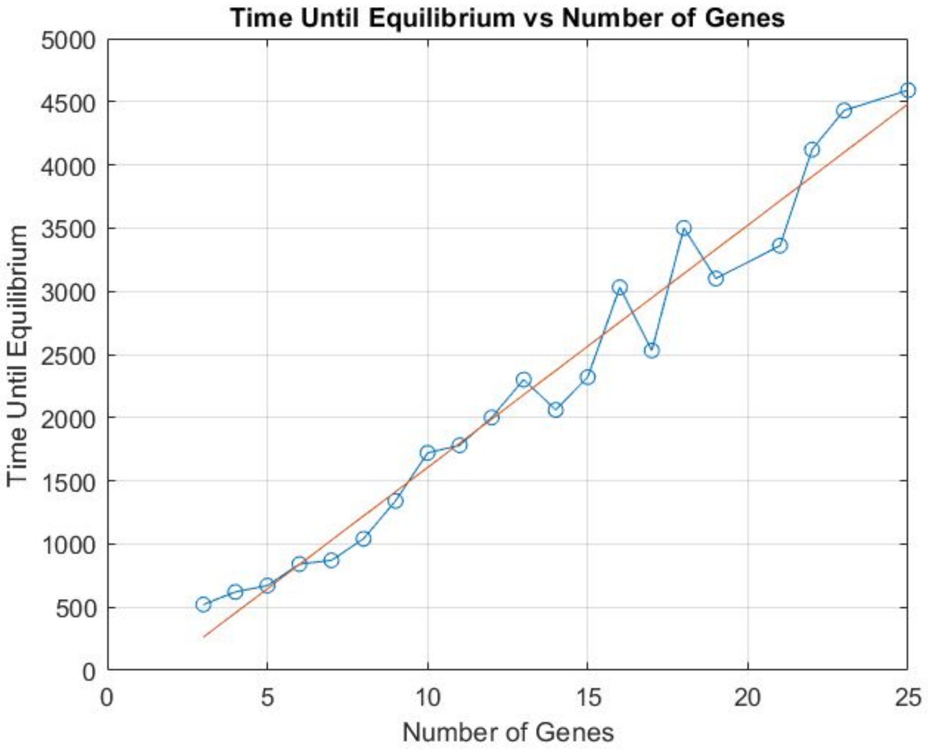
Experiment #3: Time to Recovery

- Increasing the number of genes
  - Increases the probability of mutations
  - Decreases the marginal difference between genotypes that differ by one gene

My prediction: Exponential Curve

Experiment #3: Time to Recovery

time = -313 + 192n



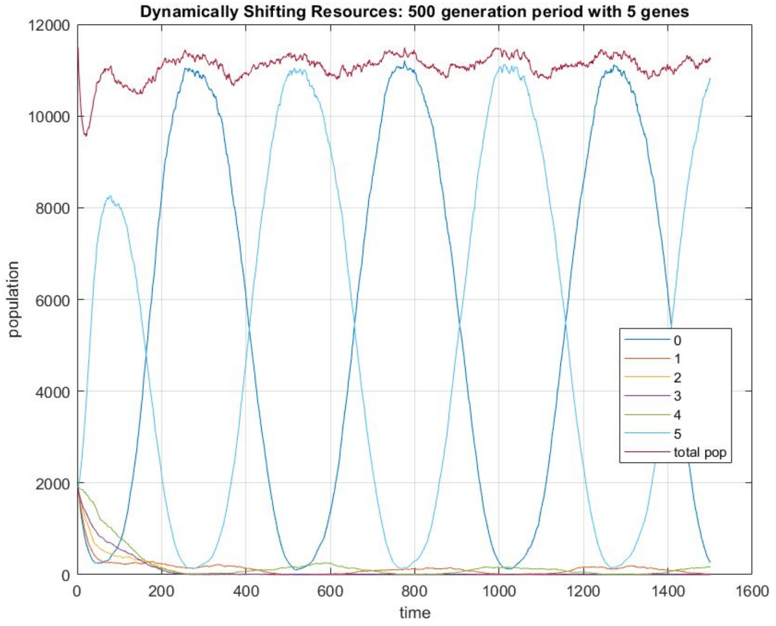
Next Steps

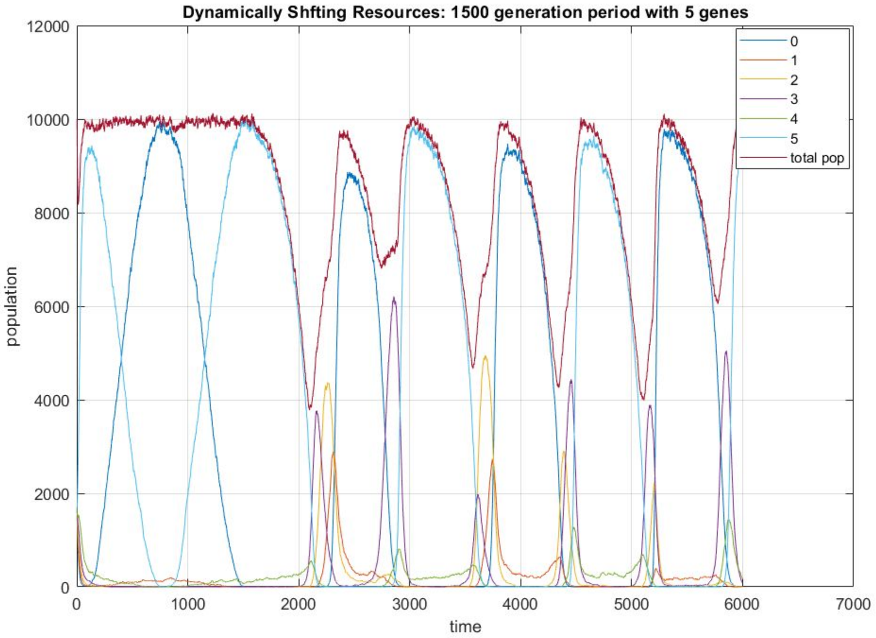
- Look at more complex dynamics of changing resources

- Make time dependent predictions

- Look at more complex gene models

Bonus: Dynamically Changing Resources





Conclusions

- Just because a nearby genotype is favored, doesn't mean we will find it in the population

- Manipulating selection forces is a potentially powerful tool to manipulate the genotype of a population

- Realistic analyses of gene transformation is not necessarily computationally feasible with my framework

Acknowledgements

- QinQin Yu
- Oskar Hallatschek
- *Evolutionary Dynamics* by Martin Nowak

Questions?